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Field monitoring and lab tests to control fabric pests

Abstract - A number of species of Tineidae moths and Dermestidae beetles can attack and damage textiles. They can cause considerable damage on wool manufactures.
In this paper several facets of the fabric pest infestation are considered. A biennial monitoring was carried out in a textile industry and it allowed to verify the presence of the Tineid moth *Tineola bisselliella* (Hummel) and of the Dermestid beetle *Anthrenus verbasci* (L.).
Lab tests on *T. bisselliella*, *A. verbasci*, *Attagenus brunneus* Faldermann, *Lasioderma serricorne* (F.) larvae were carried out to control their survival and development on a wool blanket, treated with permethrin. Larvae of *A. verbasci, A. brunneus* and *L. serricorne* were able to reach adult stage, feeding on treated wool fibres and causing evident damage.
A lab study was started to estimate the efficacy of novaluron, lufenuron and pyriproxyfen, as alternative to permethrin, to control *T. bisselliella* larvae. Both novaluron and lufenuron products caused the death of all newborn larvae of *T. bisselliella* two weeks after the treatment, whereas pyriproxyfen took three weeks. Tests conducted on 24-day-old larvae showed the complete mortality on novaluron after one week and after two weeks on lufenuron. Pyriproxyfen did not take less than 4 weeks to yield a comparable result. Moreover, visual examination showed the damage on the wool fabric.

Riassunto - *Monitoraggio e prove di laboratorio contro gli infestanti di un'industria tessile.*

Alcune specie di Lepidotteri Tineidi e Coleotteri Dermestidi sono in grado attaccare i tessuti provocando notevoli danni ai manufatti in lana.
In questo lavoro sono stati presi in considerazione diversi aspetti del problema delle infestazioni. Innanzitutto è stato effettuato un monitoraggio biennale in un'industria tessile che ha permesso di accertare la presenza di *Tineola bisselliella* (Hummel) e *Anthrenus verbasci* (L.) in diversi reparti dell'industria. Prove di laboratorio hanno permesso di accertare che larve di *A. verbasci*, *Attagenus brunneus* Faldermann, *Lasioderma serricorne* (F.) sono state in grado svilupparsi su del tessuto in lana, trattato con permetrina, causando danni evidenti.
Inoltre, è stata valutata in laboratorio l'efficacia di novaluron, lufenuron e pyriproxyfen contro le larve di *T. bisselliella*. Sia novaluron che lufenuron hanno provocato

la morte di tutte la larve neonate di *T. bisselliella* dopo due settimane dal trattamento, mentre sono state necessarie 3 settimane con pyriproxyfen. La mortalità completa delle larve di 24 giorni è stata registrata dopo 1 settimana con novaluron, 2 settimane con lufenuron e non meno di 4 settimane con pyriproxyfen. L'ispezione visiva ha però evidenziato seri danni al tessuto di lana.

Key words: novaluron, lufenuron, pyriproxyfen, permethrin, Tineidae, Dermestidae.

INTRODUCTION

A number of species of Tineidae moths and Dermestidae beetles can attack and damage textiles. Among Lepidoptera the most spread species are *Tineola bisselliella* (Hummel) (webbing clothes moth), *Tinea pellionella* L. (casemaking clothes moth) and *Trichophaga tapetzella* (L.) (carpet moth), whereas among Dermestidae, several *Anthrenus* spp. and *Attagenus* spp. (Pinniger, 1990). The species concerned posses the unusual ability to digest keratin, the chief constituent of fur, wool and feathers (Robinson, 1996).

Clothes moths and dermestid beetles can live on virgin wool; they prefer to settle in cloths including some traces of contaminants, like urine, sweat, beer, milk or juices to integrate their feeding habits. In fact pure keratin lacks some amino-acids and, generally, B-vitamins complex, essential in larval development (Busvine, 1951). In nature, these substances are available on dirty matter, whereas in a lab, where these pests are reared, the woollens diet has to be integrated with yeast and, if necessary, with cholesterol, a precursor of the ecdysone. Fraenkel *et al.* (1941) demonstrated that the minimum quantity of sterols required for a successful growth of *Dermestes maculatus* De Geer larvae is about 1 mg/3 g of food for cholesterol and 7-dehydrocholesteryl monobenzoate and less than 0.5 mg/3 g of food for 7-dehydrocholesterol.

The development cycle of these insects depends on temperature, humidity and available food. *T. bisselliella* can take from 42 to 62 days on fish meal at 23.8°C (Griswold, 1944), however on an unsuitable substrate, larvae may stop eating for 8-24 months with the cycle lasting as long as 4 years (Mallis, 1954). Lepigre (1951) referred that, under top conditions, the development cycle takes 2-3 months; Pereira (1960), who studied how temperature and humidity affect cycle time, recorded on average 54.5 days at 30.7°C, 60.9 days at 25°C and 62.8 days at 23.5 °C. In dermestids a cycle may last from 4-5 months to one year or longer. Generally one generation per year will appear with adults appearing in spring. A detailed description of the most common species and their biology was referred by Lepesme (1944) and Hinton (1945).

Several laboratory experiments have been conducted to evaluate different residual insecticides for the protection of wool and woollen materials against different species belonging to the genera *Tinea*, *Tineola*, *Anthrenus* and *Attagenus*. The effectiveness of impregnating materials with insecticide as a method for killing larvae and to prevent damage to fabrics was widely investigated (Veer *et al.*, 1991; Bry *et al.*, 1984; Mayfield

& O'Loughlin, 1980). Among the active ingredients tested, permethrin was preferred as it was found to be effective against pests for a longer duration. However, some cases of resistance in *Anthrenus flavipes* Casey (Schmidt, 1987) and other carpet beetles (Lewis & Shaw, 1988) were reported, while a few environmental aspects puzzled scientists since, as it is the case with all pyrethroids, permethrin is heavily toxic to the water fauna (Taylor, 1985).

In this work, we take into account manifold facets of the wool pests problem in order to understand the effect of infestation. The investigation was encouraged by the fact that the damaged textiles had been treated with permethrin, but nevertheless they had been infested.

First of all, a biennial monitoring was carried out in a textile industry, where several damage had been frequently found on textile products (in particular wool blankets), focusing on the seasonal development of insects, in order to develop a rational control technique.

At the same time, some laboratory tests on four different species were carried out to control their survival and development on a wool blanket, treated with permethrin. The caused damage was then examined and compared to that found in the textile industry.

Moreover a lab study was started to estimate the efficacy of some molecules as an alternative to permethrin, usually applied in wool finishing.

The present study considers active ingredients belonging to the insect growth regulators (IGR); in particular two chitin synthesis inhibitors (novaluron and lufenuron) and a juvenoid (pyriproxyfen) against *Tineola bisselliella*. Some studies considered these molecules as efficient on dermestid beetles, particularly on species of the *Trogoderma genus* (Karnavar, 1983; Klein & Burkholder, 1984; Sharma, 1994), and on moths (Gilberg & Roach, 1997). However, no studies are known to check their application on woollen substrates.

MATERIALS AND METHODS

Study on the population dynamics of pests in a textile manufacturing site.

Delta pheromone traps, activated with (E)-2,(E)-13,18:Ald (1 mg) + (E)-2,18:Ald (0.5 mg), in a Beckman polyethylene lure, were used to monitor *T. bisselliella*. Traps were set in the most critical areas such as the raw material stock, the packaging section and the finished product stock.

Food traps were used to monitor dermestid beetles (9 inside, 2 outside). They were made of plastic containers closed with a net, containing dried insects, like grasshoppers and large lepidoptera. The rather large mesh net (10x10 mm) let adults, attracted by the substrate, enter the container and lay eggs. Such innovative traps had been developed in a prior study (Pezzotta, 2003, unpublished degree thesis). The traps were substituted every month and the removed ones were placed in a conditioned chamber (26°C and 70% RH) to follow the development of laid eggs.

Monitoring took place from July to November 2004 and from May to November 2005 and was integrated with visual inspections inside and outside the textile industry.

Evaluation of the damage caused by various species of insects on the same cloth.

Lab tests were conducted on wool clothes made by cloth manufacturers, treated with permethrin during the staple dyeing stage, to check a possible attack from larvae of *Anthrenus verbasci* (L.), *Attagenus brunneus* Faldermann, *Tineola bisselliella* (Hummel), *Lasioderma serricorne* (F.). Tests were conducted on Petri dishes (Ø = 5.5 cm), with five III-IV instar larvae on each dish with wool cloth, at 26°C (± 1°C) and 70% (± 5%) humidity. Two tests were performed for each species. A weekly check was provided until the death of the larvae or adults emerging from the cocoon. This method enabled us to evaluate the kind of damage caused by various insect species on the same cloth, treated with permethrin.

Lab study of some insecticides on T. bisselliella.

A 100% wool plain weave (mass per unit area: 215±10 g/m^2), as specified in the Martindale abrasion test [EN ISO 12947-1:1998], served as reference textile through out this study. It was used to test the efficacy of two chitin synthesis inhibitors (novaluron and lufenuron) and a juvenoid (pyriproxyfen) (Table 1).

The strain of *T. bisselliella* used in the tests is reared in the laboratory of the Istituto di Entomologia agraria, Università degli Studi di Milano, where it is kept at 26±1.5°C and 60±5% RH, on a virgin wool diet integrated with cholesterol and yeast. Under these conditions the full cycle takes 45-50 days.

Four replications were performed both with newborn and 24-day-old larvae, using 20 eggs for each repetition, or fifteen 24-day-old larvae. Eggs or larvae were put on Petri dishes (Ø = 5.5 cm) with the bottom covered with a piece of treated cloth. The treatment was carried out plunging the cloth (size of the pieces 25x25 cm) in 100 mL of a solution

Table 1 - Characteristics of the active ingredients applied in tests, compared with permethrin (Tomlin, 1997).

	DL_{50} for rats mg/kg	**Mechanism of action**	**Irritating eyes and skin (rabbit)**	**Causing skin sensitivity (guinea pig)**	**WHO toxicity index (a.i.)**
novaluron	>5000	Chitin synthesis inhibitor, affecting moulting (ingestion, contact)	NO	NO	III –IV
lufenuron	>2000	Chitin synthesis inhibitor, affecting moulting (mostly by ingestion)	NO	NO	III
pyriproxyfen	>5000	Suppressor of embryogenesis and adult formation (ingestion, contact)	NO	NO	III
permethrin	430-4000	Neurotoxic (ingestion, contact), having a slight repellent effect	MILD	MODERATE	II

Table 2 - Characteristics of the products applied in the tests and relative dosage.

Composition	Dosage g/100 mL
novaluron 9.12%	0.15
lufenuron 5.32%	0.30
pyriproxyfen pure 10.86 g (=100g/L)	0.15

for 90 minutes, at the concentration set for each single product (Table 2). Once dried, each cloth piece was sprayed with a water, yeast and cholesterol solution (100:10:1) to supply all nutritive elements required for the development of larvae, as mentioned above. Tests were performed at controlled temperature and humidity: 26°C (±1.5°C), 60% (± 5%) RH. Weekly checks were performed until the death of all individuals or the emerging of adults from cocoons.

Results were submitted to ANOVA and Duncan's multiple range test ($P<0.05$). The tests were performed using the SPSS for Windows version 13.0.

RESULTS AND DISCUSSION

Population dynamics in a textile industry.

Pheromone traps set in three sections of the industry caught several *T. bisselliella* individuals.

The comparison of data of both years shows a much larger number of catches in 2004 than in 2005 (Figs 1 - 2). Most catches happened in the raw material stock where, especially in 2004, a lot of raw wool from different sources was stored. The higher number in 2004 is attributable to apparently heavily infested wool lots, in stock for a long time, which were then removed.

Almost no catching happened in the packaging section, whereas some adult individuals were caught in the finished product stock, mostly in 2005.

Food traps, set both inside and outside the industry, enabled us to monitor the presence of *Anthrenus verbasci* (L.) as well as of *T. bisselliella* and of some Psocids in several areas (Tables 3). *A. verbasci* was observed in summer, particularly outside when the hedge of *Cotoneaster* spp., surrounding the industry, flowered. Also the visual inspection allowed to verify the presence of a great number of *A. verbasci* adults on flowers. They entered inside the textile industry, facilitated by the frequent habit of leaving the doors open. It is known that adults emerge between the end of May and early August when they actively fly to and feed on the pollen and nectar of flowering plants (Woodroffe & Southgate, 1954).

Dried insects used to prepare traps are a very suitable substrate to develop both tineid moths and dermestid beetles, since they attract females looking for a substrate to lay eggs. It is worth mentioning that pheromone traps are available on the market also for some dermestid beetles, though not being so frequently applied in Italian textile industries.

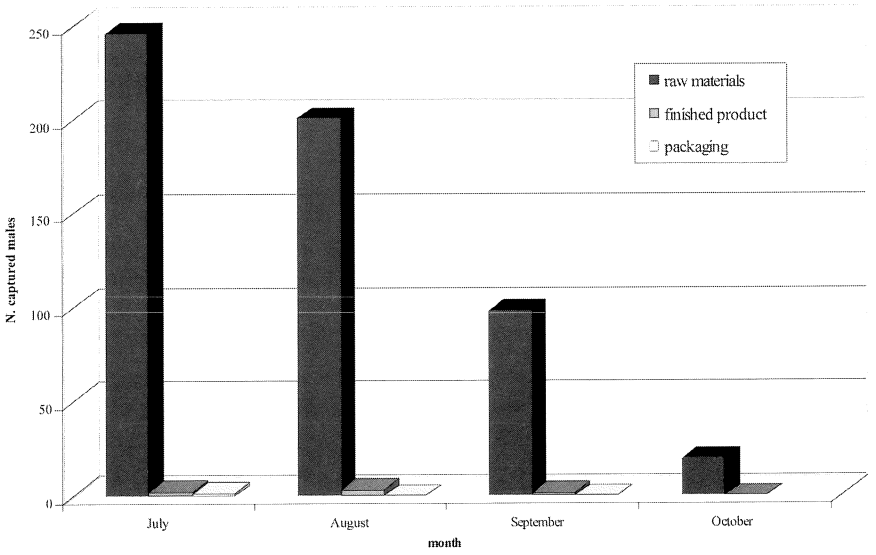

Fig. 1 - Total number of captured *T. bisselliella* adults, in different areas of a textile industry in 2004.

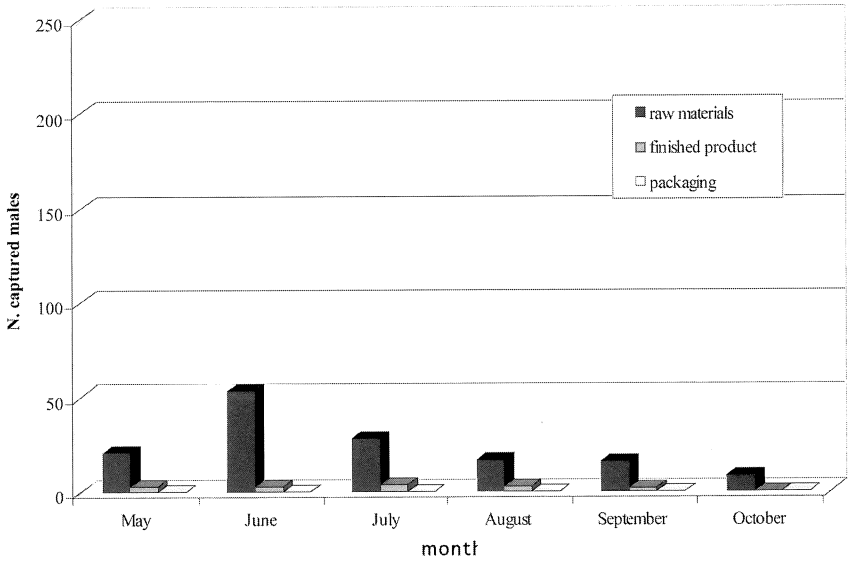

Fig. 2 - Total number of captured *T. bisselliella* adults, in different areas of a textile industry in 2005.

Table 3 - Monitoring with food traps in 2004 and 2005. T = *T. bisselliella*; A = larvae of *A. verbasci*; P = Psocids; - = nothing.

Section	Jul 04	Aug 04	Sep 04	Oct 04	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05
Raw material stock	T	T	T	T	-	-	-	-	-	-
Finished product store	-	-	A	-	-	-	A	-	-	-
Store	-	-	-	-	-	-	-	-	-	-
Assembly/ packaging	-	-	A	-	-	-	-	-	-	-
Warping	-	-	-	-	A	-	-	P	-	-
Reel stock 1	-	-	-	-	-	A	T	P	-	-
Reel stock 2	-	-	-	-	-	-	-	T	-	-
Weaving	-	-	-	-	-	-	-	-	-	-
Understairs	-	-	-	-	-	-	-	-	-	-
Outside raw material stock	-	-	-	-	-	-	A	-	-	-
Outside warping section	A	-	-	-	-	A	A	-	A	-

Damage caused by insects on the wool fabric.

It was examined the ability of *T. bisselliella, A. verbasci, A. brunneus, L. serricorne* larvae to develop on samples of wool blanket, treated with permethrin at staple dyeing, within the manufacturing process.

Results showed that while larvae of *T. bisselliella* could not develop and died 24 hours after the beginning of trials, III-IV instar larvae of *A. verbasci, A. brunneus* and *L. serricorne* were able to reach adult stage, feeding on wool fibres and causing evident damage (Fig. 3). *A. verbasci* and *A. brunneus* nibbled the cloth breaking wool threads at the bottom so that a "small area" eaten by larvae was left covered with droppings (Fig. 4). It has already been demonstrated that residual insecticide treatments using permethrin and bendiocarb are relatively ineffective in controlling wandering *A. verbasci* larvae (Hyller & Blyth, 1992; Morgan *et al.*, 1993). Morgan *et al.* (1993) hypothesized that the presence of setae on *Anthrenus* larvae may reduce the uptake of insecticide because less comes into direct contact with the cuticle.

Larvae of *L. serricorne* bore the cloth in a quite visible way (Fig. 5). Benezet *et al.* (1986) had already pointed out the low efficacy of permethrin against *L. serricorne*.

Activity of IGRs and juvenoid on newborn larvae of T. bisselliella.

At the experimented dosage (Table 2), a week after the treatment novaluron and lufenuron killed 50% of *T. bisselliella* larvae. Both novaluron and lufenuron products caused the death of all larvae two weeks after the treatment, whereas pyriproxyfen took three weeks. Pyriproxyfen is a juvenoid that acts extending the larval stage; results reported on newborn larvae show that this agent causes a slower death of larvae, compared to results obtained with the other two products (Table 5). Droppings produced by

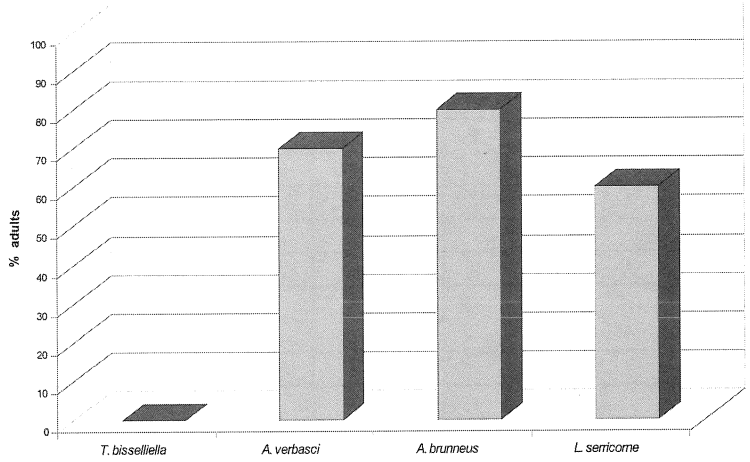

Fig. 3 - Mean percentage of emerged adults of *T. bisselliella*, *A. verbasci*, *A. brunneus*, *L. serricorne* from III-IV instar larvae grown on permethrin processed wool.

newborn larvae were observed, but wool fibres, directly examined by a stereo-microscope at 10x showed no damage.

Lufenuron seems to affect embryonic development, since the percentage of hatching is significantly lower if compared with the other two products and the check compound (Table 6). This issue needs further examination and experience.

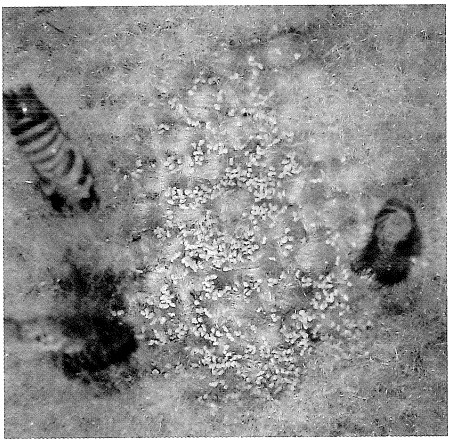

Fig. 4 - *A. verbasci* larvae: damage with droppings and exuviae.

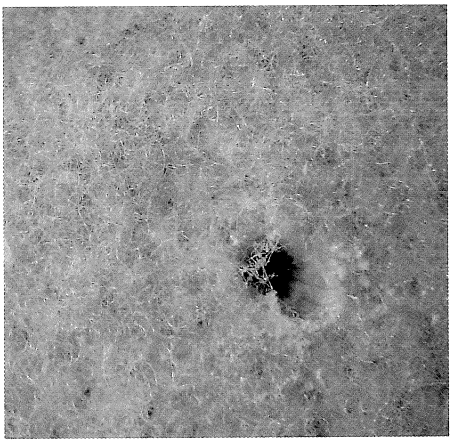

Fig. 5 - *L. serricorne*: hole produced by larvae on the cloth.

Table 5 - Mortality (%) of newborn *T. bisselliella* larvae in the weeks following the treatment. Percentages followed by the same letter in a line, are not significantly different (Duncan Test; P>0.05).

Weeks from the treatment	novaluron (% ± S.D.)	lufenuron (% ± S.D.)	pyriproxyfen (% ± S.D.)	Check (% ± S.D.)
1	49.22±17.11 bc	59.82±14.80 c	33.01±14.29 b	0.00±0.00 a
2	100.00±0.00 c	100.00±0.00 c	95.90±2.75 b	1.31±2.63 a
3	100.00±0.00 b	100.00±0.00 b	100.00±0.00 b	2.70±3.12 a

Table 6 - Percentage of hatching of *T. bisselliella* eggs. Percentages followed by the same letter, are not significantly different (Duncan Test; P>0.05).

	novaluron (% ± S.D.)	lufenuron (% ± S.D.)	pyriproxyfen (% ± S.D.)	Check (% ± S.D.)
Hatching	78.75±11.09 b	57.50±8.66 a	88.75±7.50 b	90.00±7.07 b

Activity of IGRs and juvenoid on old larvae of T. bisselliella.

Tests conducted on 24-day-old larvae show the complete mortality on novaluron after one week and after two weeks on lufenuron, because they act inhibiting the chitin synthesis. Pyriproxyfen takes not less than 4 weeks to yield a result comparable with novaluron and lufenuron, because it extends the larval stage: larvae continue to feed causing more serious damage to the cloth. (Table 7). Also Gilberg and Roach (1997) had noticed a similar phenomenon on *T. bisselliella* larvae treated with fenoxycarb.

The damage on cloth pieces treated with novaluron and lufenuron is significant, although all larvae died by the end of the second week of treatment; moreover, visual examination of the wool fibres shows the damage as well as a considerable number of browse, holes and a lot of droppings (Figs 6 - 7).

Table 7 - Mortality of 24-day-old *T. bisselliella* larvae in the weeks following the treatment. Percentages followed by the same letter in a line, are not significantly different (Duncan Test; P>0.05).

Weeks from the treatment	novaluron (% ± S.D.)	lufenuron (% ± S.D.)	pyriproxyfen (% ± S.D.)	Check (% ± S.D.)
1	100.00±0.00 c	91.67±8.39 b	0.00±0.00 a	0.00±0.00 a
2	100.00±0.00 c	100.00±0.00 c	66.67±5.44 b	0.00±0.00 a
3	100.00±0.00 c	100.00±0.00 c	86.67±5.44 b	4.98±6.38 a
4	100.00±0.00 b	100.00±0.00 b	93.33±5.44 b	4.98±6.38 a
5	100.00±0.00 b	100.00±0.00 b	96.67±3.85 b	4.98±6.38 a
6	100.00±0.00 b	100.00±0.00 b	100.00±0.00 b	4.98±6.38 a

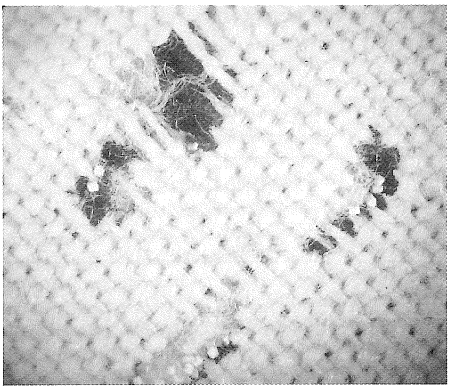

Fig. 6 - Damage on fabric treated with novaluron caused by 24-day-old larvae of *T. bisselliella*.

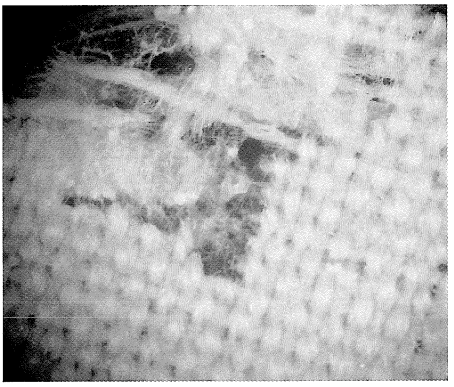

Fig. 7 - Damage on fabric treated with lufenuron caused by 24-day-old larvae of *T. bisselliella*.

CONCLUSION

The monitoring in the textile industry allowed to verify the presence of the webbing clothes moth *T. bisselliella* and of the varied carpet beetle *A. verbasci*.

In 2004 *T. bisselliella* was heavily present due to lots of heavily infested wool which was then removed, in order to significantly cut the number of captures in 2005. *A. verbasci* larvae, found in the traps in summer are associated with adult females appearing in spring that, after mating, look for a suitable substrate to lay eggs. Consequently, for the time being, these insect are the most dangerous pests against which prevention and control measures have to be taken. In fact, the permethrin treatment, usually applied in this industry, was unsuccessful against *A. verbasci* and *A. brunneus* larvae which can damage clothes just the same. The laboratory tests confirm the practical observation that dermestid beetles larvae can survive residual insecticide treatments in practical situations. There is a need to evaluate the performance of other insecticide against this beetles.

Novaluron, lufenuron and pyriproxyfen, at the indicated dosage, are very effective against newborn *T. bisselliella* larvae, less against 24-day-old larvae. Although with novaluron all of them died within a week, damage was however noticeable.

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